

Benefits of aberration correction for elemental mapping

Scientific Achievement

It has been demonstrated that C_s -correction improves the analytical resolution in EFTEM mode by a factor of up to two from 0.6nm to 0.3nm for measuring concentration profiles of Ti (Fig. 3) and O across thin oxidized TiAl films on Si substrates. This improved resolution has been used to get a more accurate measurement of the Ti layer thickness. The spatial resolution of elemental maps derived from energy filtered images can be calculated from the damping envelope of the contrast-transfer function as shown in Fig. 1 for parameters which are typical for the measurement of Ti elemental maps on a length scale below one nanometer. Fig. 2 shows two C_s -corrected images demonstrating that high-resolution can be achieved as well for zero-loss imaging (Fig. 2a) as for energy filtered imaging in the low loss region (Fig. 2b). The Si(111)-lattice planes (Fig. 2b) have a lattice distance of 0.3141nm which confirms the theoretical prediction for the resolution of C_s -corrected EFTEM shown in Fig. 1. The influence of C_s -correction on analytical imaging can be demonstrated by comparing concentration profiles across a thin Ti layer derived from energy filtered images which have been recorded with different values of C_s (Fig. 3). A width of 2.6nm can be measured for the Ti-layer if C_s is fully corrected. Higher values of C_s broaden the measured concentration profiles up to 3.7nm.

Significance

The two major benefits of energy-filtering transmission electron microscopy (EFTEM) are contrast enhancement and elemental analysis. EFTEM allows analytical measurements covering a large sample area based on two images with short exposure times. One million analytical measurements can be recorded within one minute. Using C_s -correction improves the analytical resolution in EFTEM mode by a factor of about two and can complement STEM investigations by allowing fast elemental mapping of large fields of view with sub-nanometer resolution. Therefore, C_s correction is essential for interpreting results from energy filtered imaging of nanoscaled structures. Measurements of oxide barrier widths with high statistical relevance (large field of view) are another example where C_s corrected EFTEM offers the necessary precision for applications in semiconductor industry and for microelectronic device structures in general. Development of C_c -correction (see Fig. 1) offers a further improvement of EFTEM enabling atomic scale elemental mapping.

Performers

B. Kabius, Nestor Zaluzec (ANL-MSD)

Crispin Hetherington, Angus Kirkland (University of Oxford, UK)

Benefits of aberration correction for elemental mapping

- C_s correction improves resolution for elemental mapping using energy filtered imaging (EFTEM): resolution $0.6 \Rightarrow 0.3\text{nm}$
- C_c correction has the potential of enabling atomic scale resolution for EFTEM)
- Fast elemental mapping of large fields of view with sub-nanometer resolution.
- C_s correction is essential for interpreting results from energy filtered imaging of nanoscaled structures.

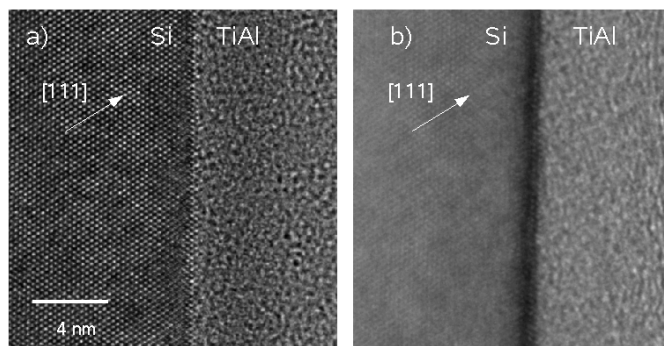


Fig. 2: TiAlO layer on Si;
a) zero-loss image,
b) energy loss: 60eV.

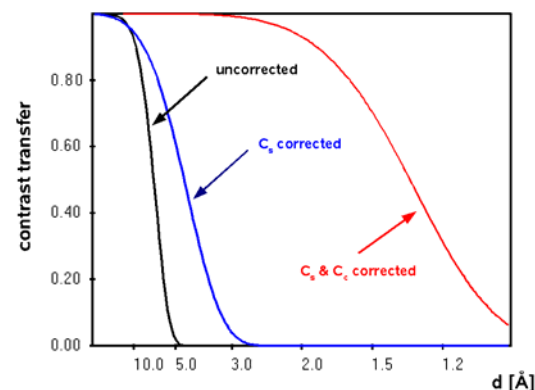


Fig. 1: C_s and C_c correction and resolution of energy filtered images

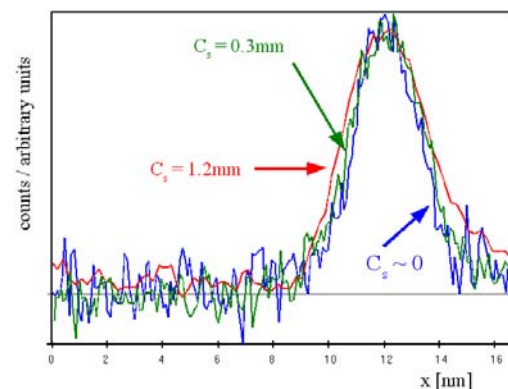


Fig. 3: Ti concentration gradients